4.17 HYDROLOGY AND WATER QUALITY

The study area with respect to hydrology and water quality includes groundwater, freshwater lakes, rivers and their tributaries, and coastal estuarine waters from the Atlantic Ocean through Charleston Harbor and the Intracoastal water up to the Pinopolis Dam at Lake Moultrie, up to the headwaters of the Wando River, and up to Popperdam Creek in the Ashley River. Topics include hydrogeology, hydrology, water quantity, and water quality. Appendix 4.17-1 contains additional information associated with this section.

4.17.1 <u>Groundwater</u>

This groundwater evaluation includes a hydrogeological description of the aquifers and confining units within the Surficial aquifer, Tertiary aquifer and Cretaceous aquifer systems located in the upper and lower Coastal Plain of South Carolina.

4.17.1.1 Hydrogeology

The study area is located in the Coastal Plain physiographic province of South Carolina. The Coastal Plain is divided, based on groundwater hydrology into the upper Coastal Plain toward the fall line (inland margin of Coastal Plain sediments) and the lower Coastal Plain toward the Atlantic Ocean (see Figure 4.17.1-1). The Coastal Plain aquifer system of South Carolina consists of a wedge-shaped sequence of deltaic and marine sediment deposits that gradually thickens from the fall line to the Atlantic Coast. Along the coast, sediments are thickest in the south, where there are approximately 3,400 feet of sediment along the South Carolina - Georgia state line. Sediments gradually decrease towards the north where there are approximately 1,300 feet of sediment at the South Carolina - North Carolina state line. Sediments in the Charleston area are approximately 2,500 feet thick (see Figure 4.17.1-2).

The Coastal Plain aquifer system consists of a series of aquifers and confining units. Aquifers are un-confined or confined saturated permeable geologic units that can transmit significant quantities of water under ordinary hydraulic gradients. Un-confined aquifers occur near the ground surface and are bounded by the water table and a confining unit at the top and bottom, respectively. The confined aquifers occur at depth and are bounded by confining units at the top and bottom. The high permeabilities of the aquifers allow for the completion of production wells as a source of water for public usage. A confining unit is a saturated geologic unit that is incapable of transmitting significant quantities of water under ordinary hydraulic gradients. Confining units may be permeable enough to transmit water in quantities significant in the study of regional groundwater flow, but their permeability is not sufficient to allow the completion of production wells.

The three aquifer systems underlying the upper and lower Coastal Plains of South Carolina in descending order from the land surface are: Surficial aquifer system, Tertiary aquifer system, and Cretaceous aquifer system. The Surficial aquifer consists exclusively of the Surficial aquifer unit. The Tertiary aquifer system is composed of the Tertiary Sand, Santee Limestone/Black Mingo confining unit (Floridan confining unit), underlain by the Tertiary Sand aquifer unit and carbonate system of the Santee Limestone/Black Mingo aquifer unit (Floridan aquifer). The Cretaceous aquifer system is composed of the following three aquifer units and three confining units in descending order from the land surface: Black Creek confining unit; Black

Creek aquifer; Middendorf confining unit; Middendorf aquifer; Cape Fear confining unit; and Cape Fear aquifer.

A generalized stratigraphic and geohydrologic column underlying Charleston, South Carolina is shown in Table 4.17.1-1. The stratigraphic and geohydrologic column shows the systems, series, geological formations, material characteristics, and thickness of the aquifers and confining units. Detailed descriptions of the three aquifer systems can be found in Appendix 4.17-1.

4.17.1.2 Groundwater Quantity

The following discussion is a description of groundwater recharge, storage, transmissivity, groundwater flow, and groundwater use of the Surficial, Tertiary Sand/Floridan, Black Creek, Middendorf, and Cape Fear aquifers in the upper and lower Coastal Plains of South Carolina.

Groundwater Recharge

Groundwater recharge into a particular aquifer occurs by precipitation onto unconfined outcrops and vertical leakance from overlying aquifers into confined sections. Although this area of South Carolina receives approximately 48 inches of precipitation per year, only a small percentage of the total rainfall recharges the surficial aquifer and out crops of the lower Tertiary and Cretaceous aquifers; largely as result of land use, surface runoff, and evapotranspiration (USGS (b), 1996).

The surficial aquifer in the lower Coastal Plain; the out crops of the Tertiary Sand/Floridan, Black Creek and Middendorf aquifers in the upper Coastal Plain; and the out crop of the Cape Fear Aquifer in the western part of Georgia are recharged by precipitation. Leakage into confined sections of these aquifers is dependent upon the condition and effectiveness of the overlying confining unit.

Two studies conducted in 1989 and 1994 indicate net recharges to the surficial aquifer in the Charleston peninsula of 4 inches/year and 2 inches/year, respectively (USGS(b), 1996). The study conducted in 1994 was based on a U.S. Geological Survey (USGS) modular groundwater-flow model MODFLOW of the Charleston peninsula. The smaller estimated net-recharge rate in the 1994 study may be explained by the nature of the abundance of impervious surfaces in Charleston, and the presence of brick drainage archways beneath the streets. The impervious surfaces result in an abundance of runoff during and following precipitation and the brick-lined drainage archways beneath the city streets act as a sink by receiving groundwater flow from the surficial aquifer. This sink tends to decrease the overall elevation of the water-table surface. The 1994 study also factored in evapotranspiration and evaporation in the few undeveloped areas in the peninsula. The 1989 study was a regional study and did not differentiate between developed and rural areas; thus net recharge was possibly overestimated for the Charleston peninsula (USGS (b), 1996).

Vertical leakance is expressed as the ratio of hydraulic conductivity to the thickness of sediments through which vertical flow must occur, and whose units are in per day (d^{-1})(USGS (a), 1996). Little data are available on vertical hydraulic conductivity in the South Carolina Coastal Plain. Therefore, the vertical leakance values are based on results from a study on the Surficial, Tertiary Sand/Floridan, and Cretaceous aquifer conducted by the USGS in 1996.

Vertical leakance from the Surficial and Tertiary Sand/Floridan aquifers to the Black Creek aquifer was lowest in the costal area of Beaufort, Jasper, Colleton, and southern Charleston counties ($1.0 \times 10^{-9}\ d^{-1}$) and highest ($>1.0 \times 10^{-5}\ d^{-1}$) near the Fall Line in the upper Coastal Plain. Vertical leakance between the Black Creek and Middendorf aquifers ranged from $1.0 \times 10^{-9}\ d^{-1}$ in the southern part of the Coastal Plain and the Charleston area to $1.0 \times 10^{-5}\ d^{-1}$ in Aiken and Barnwell counties. The vertical leakance between the Middendorf aquifer to the Cape Fear aquifer is relatively low and homogeneous throughout the Coastal Plain. There is little exchange of water between these two aquifers. The vertical leakance values were highest in the northern Pee Dee region and lowest in the southern part of the state ranging from $1.0 \times 10^{-9}\ d^{-1}$ to $1.0 \times 10^{-7}\ d^{-1}$ (USGS (a), 1996).

<u>Groundwater Storage Capacity</u>

The storage of confined and unconfined aquifers is expressed by a dimensionless parameter called the storage coefficient. The storage coefficient is proportional to the yield of the aquifer.

An aquifer storage coefficient for a confined aquifer is defined as the volume of water that a confined aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. In confined aquifers, storage coefficients range from $5x10^{-5}$ to $5x10^{-3}$. Storage coefficients of $1x10^{-4}$ and $3x10^{-4}$ were reported for the confined portions of the Tertiary Sand/Floridan , Black Creek, Middendorf, and Cape Fear aquifers (USGS (a), 1996).

An aquifer storage coefficient for an unconfined aquifer is defined as the volume of water that an unconfined aquifer releases from storage per unit surface area of aquifer per unit decline in the water table. In unconfined aquifers, storage coefficients range from 0.01 to 0.3. The storage coefficient for the unconfined outcrops of the Tertiary Sand/Floridan, Black Creek, Middendorf, and Cape Fear aquifers and the Surficial aquifer was reported at 0.2 (USGS (a), 1996).

The higher storage coefficients in unconfined aquifers indicate higher yields than the confined aquifers. Higher yields in unconfined aquifers result because releases from storage in unconfined aquifers represent an actual dewatering of the soil pores, whereas releases from storage in confined aquifers represents only the secondary effects of water expansion and aquifer compaction caused by changes in the fluid pressure.

<u>Transmissivity</u>

Transmissivity can be expressed as the measure of the volume of water that can pass horizontally through the fully saturated thickness of the aquifer under a hydraulic gradient of 1 ft/ft. The units of transmissivity are cubic feet per day per square foot of aquifer material $(ft^3/d)/ft^2$, simplified to ft^2/d. Aquifer transmissivities vary in the South Carolina Coastal Plain due to changes in the type and composition of aquifer material that result from depositional and post-depositional processes such as solution or precipitation of minerals (USGS (a), 1996).

Transmissivities in the South Carolina part of the Floridan aquifer system range from approximately 750 to 50,000 ft^2/d (USGS (a), 1996). Transmissivities are the greatest in the southeastern part of the state, where aquifer thicknesses are the greatest. Transmissivities in the Tertiary Sand aquifer range from 500 to 2,500 ft^2/d.

Transmissivities in the Black Creek aquifer range from approximately 500 to 9,000 ft^2/d (USGS (a), 1996). The permeability of the Black Creek aquifer is relatively uniform in the northeastern part of the Coastal Plain (USGS (b), 1996). As a result, the transmissivity increases to a maximum as the aquifer thickness increases toward the coast, then tends to remain fairly constant as the aquifer thickness and permeability remain relatively uniform. The permeability of the aquifer in the southwestern part of the upper Coastal Plain is greater than that of the northeastern part because more coarse-grained sand and less clay are present. The permeability and transmissivity of the aquifer are much less toward the southern coast due to the presence of more fine-grained clay sediments than elsewhere in the aquifer (USGS (c), 1994).

The transmissivity of the Middendorf aquifer ranges from 300 to 30,000 ft^2/d. In the upper Coastal Plain, the transmissivity of the Middendorf aquifer increases from the Fall Line toward the coast because of the thickening of the aquifer, then reaches a maximum in a band in the lower part of the upper Coastal Plain. The transmissivity of the Middendorf aquifer decreases in the lower Coastal Plain because permeability of the sediments decreases. In the band of maximum transmissivity, the permeability and transmissivity are greater in the southwest than in the northeast because the sediments in the southwest are generally of similar thickness but consist of less clay and more coarse-grained sand. Although the transmissivity is less in the lower Coastal Plain part of the Middendorf aquifer, it is still greater than that of adjacent aquifers (USGS (c), 1994).

The hydraulic characteristics of the Cape Fear aquifer are difficult to determine because data are limited. It is doubtful that the transmissivity of the Cape Fear aquifer is very high anywhere in South Carolina due to the abundance of low permeability clays. On the basis of groundwater flow modeling, transmissivity of the Cape Fear aquifer ranges from about 1,000 to 3,600 ft^2/d. The area of greatest transmissivity is in the southwestern part of the lower Coastal Plain (USGS (c), 1994).

Groundwater Flow

Southeastern Coastal Plain aquifers in South Carolina are part of the much more extensive Atlantic Coastal Plain aquifer system. Generally, the regional flow in this system is parallel to the Atlantic coast, from the southwest to the northeast except for the Floridan aquifer system, where flow is perpendicular to the coast. In South Carolina, superimposed on the regional flow direction is a component of flow that moves downward from the Fall Line into the deep-flow system underlying the Lower Coastal Plain. From the deep-flow system, groundwater moves upward by vertical leakage to the shallow aquifers. Therefore, water discharges either to the Atlantic Ocean or surficial aquifer. Superimposed upon this natural discharge regime is artificial discharge caused by groundwater pumping. Since the early 20th Century, pumping has caused sub-regional changes in the flow pattern and has altered the overall regional flow paths (USGS (a), 1996). Flow patterns of the Surficial, Tertiary Sand and Floridan, Black Creek, Middendorf, and Cape Fear aquifers are described in the following paragraphs.

Groundwater in the unconfined surficial aquifer moves from higher elevations at topographic divides toward surface waters. The primary direction of the hydraulic gradient of groundwater in surficial aquifer in the Charleston area is toward the Cooper, Wando, Ashley, and Edisto Rivers; Charleston Harbor, and the Atlantic Ocean. Water leaves the surficial aquifer as a result of evapotranspiration or discharge to surface water bodies (USGS (b), 1996).

Pre-development flow in the Floridan aquifer was from northwest to southeast, generally perpendicular to the coastline. Pre-development water-levels in the aquifer were approximately 25-feet above sea level. Groundwater recharge entered the aquifer at its outcrop area near Orangeburg and Lake Marion, and flowed toward the southeast. Large-scale development of the aquifer began during the 1960's, especially in the area approximately 20 miles northwest of Charleston. Water level measurements collected in 1982 show a cone of depression in the aquifer potentiometric surface. By the early 1990's, extensive development combined with poor hydraulic characteristics resulted in large depressions in the potentiometric surface with the lowest water-level (approximately -65-feet) in southern Berkeley County. At present, the regional groundwater flow of the aquifer is reversed from pre-development flow direction in the Charleston area and is toward these cones of depressions (USGS (d), 1997).

Groundwater in the Black Creek aquifer flows along short flow paths from the inter-stream recharge areas to streams in the upper Coastal Plain and along longer flow paths from the upper to the lower Coastal Plain. Flow in the lower Coastal Plain prior to pumpage was generally to the east or northeast. Discharge is to streams in the upper Costal Plain, to the overlying Tertiary Sand and Floridan aquifers by diffuse upward leakage in the lower Coastal Plain, and to wells throughout the area. The effects of pumpage on the potentiometric surface and on flow patterns are greatest in the vicinity of Myrtle Beach. Flow prior to pumpage has had a much greater effect on the distributions of water quality constituents than present flow because of the slow rate of water movement and the relatively recent development of pumpage centers (USGS (c), 1994).

Groundwater in the Middendorf aquifer flows along short flow paths from the in stream recharge areas to streams in the upper Coastal Plain and along longer flow paths from the upper to the lower Coastal Plain. Flow in the lower Coastal Plain prior to pumpage was generally toward the east or northeast, nearly parallel to the coast. One of the major reasons for the direction of flow and head distribution in the Middendorf aquifer is that the permeability of the confining unit in Paleocene sediments overlying aquifers in Cretaceous sediments is less in the southwest than in the northeast. Therefore, the confining unit is more effective in inhibiting leakage between the aquifers in Cretaceous sediments and overlying aquifers in the southwestern part than the northwestern part of the lower Coastal Plain. Thus, prior to pumpage of water from the Middendorf aquifer and other Cretaceous aquifers, upward discharge from the aquifers in Cretaceous sediments in the northeast decreased the hydraulic head, resulting in flow in that direction. Flow prior to pumpage has had a much greater effect on the distribution of water-quality constituents than present flow because of the slow rate of water movement and the relatively recent development of the pumpage centers. Discharge is to streams in the upper Coastal Plain, to the Black Creek aquifer by diffuse leakage in the Lower Coastal Plain, and to wells throughout the area (USGS (c), 1994).

Groundwater in the Cape Fear aquifer flows from the recharge area in Georgia across the lower Coastal Plain of South Carolina and into southeastern North Carolina, approximately parallel to the Atlantic coast. In the upper Coastal Plain of South Carolina, sparse data indicate that water flows from the inter-stream recharge areas toward streams in patterns similar to those of the Middendorf aquifer. Discharge from the Cape Fear aquifer is by diffuse leakage to the overlying Middendorf aquifer near streams in the upper Coastal Plain of South Carolina and throughout the lower Coastal Plain of South Carolina and southeastern North Carolina (USGS (c), 1994).

Groundwater Use

The Surficial aquifer system is an inexpensively developed source of domestic water supply. Water-bearing sand and shell beds generally yield between 10 and 20 gpm to individual wells. However, this system does not yield water in every part of the lower Coastal Plain and the system is too thin or clayey to provide even the small amount of water needed for domestic consumption. (Berkeley County Land Use Plan, 1982).

The Floridan and Tertiary Sand aquifers are the two most productive aquifers in South Carolina. The Floridan and Tertiary aquifer system underlies nearly all of Berkeley, Charleston, and Dorchester counties and provides an important source of potable water for these three counties. Well depths range from 40 to 60 feet in the outcrop areas around Moncks Corner to about 450 feet in the southernmost part of Berkeley County.

The Middendorf and Black Creek aquifers are the most heavily used aquifers in the South Carolina Coastal Plain. The volume of groundwater water drawn from the Cape Fear aquifer is insignificant compared to the volumes withdrawn from the Black Creek and Middendorf aquifers. Major withdrawal centers for the Black Creek aquifer are the Myrtle Beach area, Georgetown, and small towns in the Pee Dee region. The Midendorf aquifer is utilized at Aiken, the Savannah River Plant, Sumter, Florence, Summerville, Mount Pleasant, Isle of Palms, Sullivans Island, Walterboro, St. Stephens, Orangeburg, and numerous other small towns and industrial facilities throughout the Coastal Plain.

In the area of Charleston, Berkeley, and Dorchester counties, Mount Pleasant and Summerville are the major users of groundwater sources. Secondary users include Sullivans Island, Isle of Palms, St. Stephens, and Jamestown. Some water is withdrawn for irrigation by resorts on the Isle of Palms and Kiawah and Seabrook Islands.

Mount Pleasant has withdrawn water from the Middendorf aquifer since 1968, when the first of six wells was drilled. Daily production averages in 1993 were 5.1 mgd with daily peak demands of 6.0 mgd. Withdrawals have increased from 2.4 mgd in 1984 to 5.1 mgd in 1993 (USGS (a), 1996).

Currently the town of Summerville utilizes three Middendorf aquifer wells for emergency use only. The Summerville Commissioners of Public Works ceased withdrawal from the Middendorf aquifer as a primary source in 1994 and began using the Edisto and Ashley Rivers as the surface-water sources.

4.17.1.3 Groundwater Quality

The SCDHEC has identified three groundwater classifications (GA, GB, and GC), in the State of South Carolina. A description of each classification is presented in Table 4.17.1-2. Groundwater classifications are based on desired uses, not on natural or existing water quality, and are a legal means to obtain the necessary treatment of discharged wastewater to protect designated uses. Actual water quality may not have a bearing on an aquifer's classification. An aquifer may be reclassified if desired or existing public uses justify the reclassification and the water quality necessary to protect these uses is attainable. A classification change is an amendment to a State regulation and requires public participation, SCDHEC Board approval, and General Assembly approval. All groundwaters within the study area are classified as GB, as per definition in Table 4.17.1-2.

The groundwater quality standards for each groundwater classification mandated by the SCDHEC are shown in Table 4.17.1-3. The groundwater quality standards are used as in-stream groundwater quality goals to maintain and improve groundwater quality and also serve as the foundation of the Water Pollution Control Program established by the SCDHEC. The groundwater quality standards are used to determine permit limits for point source treated wastewater dischargers, and non-point sources that may impact groundwater quality. Wasteload allocation models are used to predict the impact a wastewater discharger has on a receiving aquifer. The predicted impacts are used to set limits for different pollutants on the NPDES permits issued by the USEPA. The NPDES permit limits are set so that, as long as a permittee (wastewater discharger) meets the established permit limits, the discharge should not cause a standards violation in the receiving aquifer. All discharges to the waters in the State of South Carolina require NPDES permits and must abide by those limits, under penalty of law.

Groundwater quality throughout the Coastal Plain of South Carolina is good for most uses. Water quality impairment or limitation on the use of groundwater for public supply are caused primarily by natural geochemical processes rather than by widespread degradation of water quality by human activities. Groundwater contamination induced by human activities generally is localized and associated with chemical spills, waste disposal, septic tanks, landfills, oil and gas brine pits, underground storage tanks, above ground storage tanks, land application or treatment, agricultural activities, injection wells, and saltwater intrusion.

Groundwater quality has been evaluated in several programs conducted by the USGS and the SCDHEC. Numerous groundwater wells throughout the Coastal Plain have been sampled and water quality data documented in these programs. Public supply groundwater wells are sampled every 3 years. Monitoring wells near sites of potential contamination are sampled quarterly or biannually along the coast; samples are collected semiannually to monitor for saltwater intrusion.

Water quality impairment from natural processes reflects the effect of flow patterns and the mineralogy of the sediments. Concentrations of most constituents in the Surficial, Tertiary/Floridan, Black Creek, Middendorf, and Cape Fear aquifers in the upper and Coastal Plains are small near recharge areas in the upper Coastal Plain close to the Fall Line and increase down gradient toward the Atlantic Coast.

Sediments of the Tertiary/Floridan, Black Creek, Middendorf, and Cape Fear aquifers deposited in nonmarine environments in the upper Coastal Plain contain little, if any, calcium carbonate sodium-rich clay minerals. Sediments in nonmarine environments consist primarily of silicate materials that react slowly with groundwater. Therefore, concentrations of dissolved solids are less than the parts of the aquifers in the lower Coastal Plain consisting of transitional and marine sediments because of the slow dissolution and low solubility of the silicate minerals (USGS (c), 1994).

Surficial Aquifer

Water quality in the unconfined surficial aquifer is locally more variable than the underlying confined portions of the Tertiary/Floridan, Black Creek, Middendorf, and Cape Fear aquifers, because the surficial aquifer is more likely to be affected by land use. Contaminated groundwater in the surficial aquifer affects surface water bodies because of their close proximity to the ground surface and are hydraulically connected in some areas. Groundwater in the Surficial aquifer in the lower Coastal Plain has deteriorated in some limited areas because of contamination from industrial, county and municipal, agricultural, and domestic sources. Four areas in the Charleston area where the surficial aquifer was contaminated are discussed in the following paragraphs. Potential areas of soil and groundwater contamination are discussed in Section 4.14.

- The groundwater in the vicinity of the surface dust impoundment owned by the Macalloy Corporation is contaminated with chromium and a groundwater corrective action system was constructed in response to this condition. The surface water affected by the groundwater contamination is the Cooper River.

- The groundwater in the vicinity of the Shipyard Coal Terminal is contaminated with nitrates. The surface water affected by the groundwater contamination is the Cooper River.

- The groundwater in the vicinity of land owned by the National Park Service on Concord Street in the City of Charleston was contaminated with metals and organic compounds as a result of unpermitted disposal by the previous owners (SCE&G, City of Charleston, and City of Charleston Housing Authority). The surface water affected by the groundwater contamination is the Cooper River.

- The groundwater in the vicinity of the property owned by Charleston Resource Recovery is contaminated with volatile organics from an unknown source. The surface water affected by the groundwater contamination is Shipyard Creek.

Water quality in the surficial aquifer near the Atlantic coast may contain concentrations of chloride that exceed the 250 mg/l secondary drinking water standard as a result of the mixing of freshwater with saltwater, but the problem is not extensive. Although the water from the surficial aquifer exceeds the standards for nitrate and fluoride in some areas, these areas appear to be limited in areal extent. The drinking water standard most commonly exceeded in water from the surficial aquifer is for dissolved iron, 300 ug/l (USGS (E), 1986).

Tertiary Sand, Santee Limestone/Black Mingo Aquifer (Floridan Aquifer)

The Floridan and Tertiary Sand aquifer systems are discussed collectively to illustrate their hydraulic connection and the water quality changes caused by geologic changes from limestone to sand in the Floridan and Tertiary Sand aquifers, respectively. Concentrations of dissolved solids are less than 50 mg/l and pH is less than 6.0 near recharge areas in the upper Coastal Plain, but both increase sharply down gradient toward the Atlantic coast with the increase of calcareous material in the aquifer. Dissolved solids concentrations also increase in the lower Coastal Plain to several hundred milligrams per liter, and the water quality is dominated by calcium and bicarbonate ions. Hardness of the groundwater changes from soft in the upper Coastal Plain to hard in the lower Coastal Plain. Concentrations of iron exceed the 300 ug/l secondary drinking water standard in some areas in the upper Coastal Plain (USGS (e), 1986).

Mixing of freshwater with saltwater results in a dominance of chloride and sodium ions in parts of both aquifers along the Atlantic coast. Natural concentrations of chloride exceed the 250 mg/l secondary drinking water standard in many areas in the lower Coastal Plain (USGS (e), 1986).

Black Creek Aquifer

Water quality within the Black Creek aquifer changes significantly from the upper Coastal Plain near recharge areas to the lower Coastal Plain near the Atlantic coast. Sediments in the upper Coastal Plain of the Black Creek aquifer were deposited in a nonmarine environment and are dominated with silica and contain little, if any, calcium carbonate and sodium-rich clay minerals. Therefore, concentrations of most dissolved constituents are low in the upper Coastal Plain because silica reacts slowly with water and has a low solubility with water. Concentrations of several constituents in the groundwater of the Black Creek aquifer increase significantly down gradient toward the lower Coastal Plain, where sediments were deposited in marginal-marine to marine environments. Minerals in the marine sediments of the Black Creek aquifer consist primarily of calcium carbonate and sodium. Calcium carbonate and sodium are more soluble and react more rapidly with the groundwater (USGS (c), 1994).

Middendorf Aquifer

The quality and geochemistry of water in the Middendorf aquifer are similar to those of the Black Creek Aquifer. The primary difference between the two aquifers is that the nonmarine sediments in the upper Coastal Plain of the Middendorf aquifer cover a larger area than the Black Creek aquifer.

Water quality within the Middendorf aquifer changes significantly from the upper Coastal Plain near recharge areas to the lower Coastal Plain near the Atlantic coast due to changes in geochemistry similar to the Black Creek aquifer. Sediments in the upper Coastal Plain of the Middendorf aquifer were deposited in a nonmarine environment and are dominated with silica and contain little, if any, calcium carbonate and sodium-rich clay minerals. Concentrations of most dissolved constituents are low in the upper Coastal Plain because silica reacts slowly with water and has a low solubility with water. Concentrations of several constituents in the groundwater of the Middendorf aquifer increase significantly down gradient toward the lower Coastal Plain, where sediments were deposited in marginal-marine to marine environments. Minerals in the marine sediments of the Middendorf aquifer consist primarily of calcium carbonate and sodium. Calcium carbonate and sodium are more soluble and react more rapidly with the groundwater (USGS (c), 1994).

Cape Fear Aquifer

Concentrations of several dissolved constituents in the Cape Fear aquifer increase from the upper Coastal Plain toward the lower Coastal Plain along the Atlantic coast and toward the northeast, as indicated by the concentrations of dissolved constituents. Dissolved constituents resulting from geochemical processes similar to those in the Black Creek and Middendorf aquifers is unknown because of limited data on the composition of the Cape Fear aquifer. The most probable explanation of the quality of water in the Cape Fear aquifer is the result of the combined effects of groundwater flow patterns on the flushing of saltwater. The effects of incompletely flushed dilute saltwater probably dominate the water quality of most, if not all of the Cape Fear aquifer. Saltwater intruded into the aquifer during a series of transgressions of the sea that have occurred since the nonmarine sediments were deposited. Insufficient time has passed since intrusion to allow freshwater to completely flush the saltwater from the aquifer because of the low permeability of the sediments. The incomplete flushing causes relatively high concentrations of dissolved solids, dissolved sodium, and dissolved chloride (USGS (c), 1994).

Water quality differs vertically in the Cape Fear aquifer more than the other aquifers in the upper and lower Coastal Plains of South Carolina. The vertical variability is due to the proximity of the freshwater-saltwater interface, the incomplete flushing of dilute saltwater, and to the horizontal and vertical discontinuity of the permeable sediments. The discontinuity results from a poor hydraulic connection among the different gravel and sand beds in the aquifer. Vertical differences in water quality are greatest near the freshwater-saltwater interface in the lower Coastal Plain, where concentrations of dissolved solids are the greatest and increase with depth (USGS (c), 1994).

4.17.2 Surface Waters

4.17.2.1 Surface Water Basins

The risk to surface water quality from a new port on Daniel Island, Charleston Naval Base or expansion of the existing Columbus Street Terminal will primarily result from stormwater runoff. Most impacts will be limited to the surface waters in the immediate vicinity of the site. However, off-site operations associated with port activity such as the disposal of bilge and ballast wastes from ships, dredging operations required to maintain shipping channels, rail transportation and hazardous material spills from ships expands the area where surface water may be threatened. Additionally, hazardous constituents may be transported upstream and downstream of the port site during the diurnal tidal cycle. The study area with respect to water quality includes the freshwater lakes, rivers and their tributaries and coastal estuarine waters form the Atlantic Ocean through Charleston Harbor and the Intracoastal Waterway up to the Pinopolis Dam at Lake Moultrie, up to the headwaters of the Wando River and up to Popperdam Creek in the Ashley River. The effects on salinity concentrations and shoaling conditions in Charleston Harbor resulting from the re-diversion of the Santee River through the Pinopolis Dam into the Cooper River were also discussed.

Surface waters within the study area includes fresh waters and estuarine salt waters located in the southern portion of the Catawba-Santee Watershed (see Figure 4.17.2-1). The Catawba-Santee Watershed includes approximately 5,342 square miles of area in the State of South Carolina and is divided into the, Catawba Wateree River Basin (2,381 square miles), Santee River Basin (1,208 square miles), Cooper River Basin (830 square miles), Ashley River Basin (587 square miles) and Coastal Basin (334 square miles). These five basins are divided into 47 sub-basins or hydrologic units. The hydrologic unit names shown in Figure 4.17.2-1 and Table 4.17.2-1 are the USDA Soil Conservation Service 11-digit codes for South Carolina.

The study area includes the eight sub-basins of the Cooper River Basin encompassing approximately 830.6 square miles, the two sub-basins of the Coastal Basin encompassing approximately 334.5 square miles and one of the five sub-basins in the Ashley River Basin, approximately 75 square miles. The remaining four sub-basins in the Ashley River Basin, eleven sub-basins of the Santee River Basin and the twenty-one sub-basins from the Catawba Wateree River Basin are not included in the study area because they are buffered from potential water quality impacts in the vicinity of the confluence of the Cooper, Wando and Ashley Rivers and Charleston Harbor due to their distance form the alternative port sites. Additionally, the Pinopolis Dam at The south end of Lake Moultrie blocks tidal flow from the Cooper River Basin into the Santee River and Catawba Wateree River basins.

The Cooper River, Ashley River, and Coastal Basins originate in the lower Coastal Plain and flow through the Coastal Zone Region. The sub-basins or hydrologic units within these three basins and within the study area encompass approximately 1,240 square miles. There are approximately 1,184.7 stream miles and 243.6 square miles of estuaries in the study area.

A general description of the sub-basins and surface water bodies in the Cooper River, Ashley River, and Coastal Basins is presented in the following paragraphs and a summary is included in Table 4.17.2-1.

Cooper River Basin

The Cooper River Basin has eight sub-basins and is approximately 830 square miles. There are approximately 1,170 stream miles and 45 square miles of estuarine areas in this sub-basin. Table 4.17.2-1 provides data on the eight sub-basins in the Cooper River Basin; the areas encompassed by land, water and estuaries, stream miles and major surface water bodies.

The Catawba-Wateree and Santee River Basins are not included in the study area. However, a brief description of the major rivers within these two basins is included to recognize the origins of freshwater flow into the Cooper River Basin. The Catawba River Crosses the South Carolina/North Carolina State boundary near Charlotte, North Carolina flowing through Lake Wylie and into Fishing Creek Reservoir, Cedar Creek Reservoir, and Great Falls Reservoir. The Catawba River flows out of Cedar Creek Reservoir and joins Big Wateree Creek to form the Wateree River which flows through Wateree Lake. The Wateree River merges with the Congaree River Basin downstream to form the Santee River.

The Santee River flows into Lake Marion and is either diverted east through the Wilson Dam into the Santee River or south into the Cooper River Basin through a 4-mile diversion canal into Lake Moultrie. Flow from Lake Moultrie discharges through the Pinopolis Dam at the Jefferies Hydroelectric Plant into the Tailrace Canal, merges with the Wadboo Swamp to form the West Branch Cooper River. The West Branch Cooper River is an 18 mile meandering natural channel, bordered by extensive tidal marshes and old rice fields, flowing from the Tailrace Canal to the confluence with the East Branch Cooper River. The East Branch Cooper River is a tidal slough throughout its 8 mile reach. The Cooper River is formed at the confluence of the West and East Branch Cooper rivers and receives flows from Tidal Creek, Grove Creek the Back River, Flag Creek, Slack Reach, Yellow House Creek, Goose Creek, Filbin Creek, Noisette Creek, Clouter Creek, Shipyard Creek, Newmarket Creek, and the Wando River before draining into the Charleston Harbor and the Atlantic Ocean.

On the Cooper River, from the confluence of the West Branch Cooper River and East Branch Cooper River to Flag Creek, industries are located along the west bank of the river. The east bank is dominated by extensive Spartina alterniflora salt marshes. Downstream of Flag Creek, the main channel in the Cooper River was dredged to a depth of 42 feet by the USACOE for navigational purposes (USGS (F), 1996). Industries dominate the west bank of the river, and the east bank contains some industries and large dredge-material disposal areas on Daniel Island, in the vicinity of Clouter Creek, and in the vicinity of Yellow House Creek east of the Naval Weapons Station.

There is one additional major water body in the Cooper River Basin. The Wando River is a tidal slough that tapers in width from about 2,600 feet at its mouth to a narrow tidal creek in the vicinity of Ward Bridge approximately 22 miles upstream of its confluence with the Cooper River. The banks of the river are dominated by extensive Spartina alterniflora marshes. Detyns Shipyard is located near the town of Cainhoy and the SCSPA's Wando River Terminal is located in the lower part of the river. There is some residential development along the east bank of the Wando River. Development along the Wando River has been encouraged with the completion of the Mark Clark Expressway.

Ashley River Basin

The Ashley River Basin includes five sub-basins of approximately 587 square miles. The study area only includes the Ashley River Sub-Basin (approximately 75 square miles) because this sub-basin represents the entrance to the Ashley River through Charleston Harbor. There are approximately 13.8 stream miles and 13.9 square miles of estuarine area in the sub-basin. Table 4.17.2-1 shows the area of land, water and estuaries, stream miles and major surface water bodies in the Ashley River Sub-Basin.

Four sub-basins in the Ashley River Basin are not included in the study area. A brief description of the swamps, streams and rivers within the Cypress Swamp (03050202-010), Cypress Swamp/Ashley River (03050202-020), Dorchester Creek/Eagle Creek (03050202-030), and Stono River (03050202-050) sub-basins are included to recognize the origins of freshwater flow to the Ashley River Sub-Basin. The Stono River Sub-Basin enters the lower Ashley River through Wappoo Creek. The headwaters of the Ashley River are comprised of Cypress Swamp, Dorchester Creek, Eagle Creek and their tributaries. Saw Mill Branch flows past the town of Summerville and is joined by Rose Creek to form Dorchester Creek, which flows to the Ashley River. Eagle Creek receives flows from Chandler Bridge Creek, Spencer Branch, and Federwitz Branch before draining in the Ashley River. The Cypress Swamp receives flows from Captains Creek, Platt Branch, Rumphs Hill Creek, Tina Branch and Hurricane Branch. The confluence of Cypress Swamp and Hurricane Branch forms the headwaters of the Ashley River near the town of Summerville. The Ashley River then flows through Bobs Lake and Schultz Lake to Bacon Bridge and drains into the lower Ashley River in the Ashley River Sub-Basin.

The segment of the Ashley River in the Ashley River Sub-Basin originates at Bacon Bridge. The Ashley River flows downstream and receives drainage from Coosaw Creek, Olive Branch, Sawpit Creek, Popperdam Creek, Macbeth Creek, Keivling Creek, Church Creek, Bulls Creek, Duck Island Canal, Brickyard Creek, and Orangegrove Creek, before draining into the Charleston Harbor and the Atlantic Ocean.

The Ashley River is a tidal slough that extends approximately 28 miles from the peninsula of Charleston to Cypress Swamp. The banks of the Ashley River are dominated by extensive Spartina alterniflora marshes. Residential developments are located along much of the river. Industrial and commercial facilities are located on the east bank of the lower Ashley River in between Church Creek and Orange Grove Creek. Spartina alterniflora salt marshes occupy the east bank of the lower Ashley River and dominate the east and west banks north of Church Creek up to the headwaters of the Ashley River.

Coastal Basin

The Costal Basin includes two sub-basins of approximately 334 square miles. There are 183 square miles of estuarine areas in this sub-basin. Table 4.17.2-1 shows the two sub-basins in the Coastal Basin and their respective areas encompassed by land, water and estuaries, stream miles, and major surface water bodies.

The Intracoastal Waterway and the Charleston Harbor Estuary are the two major water bodies in the Coastal Basin. The Intracoastal Waterway is the primary stream running through the Coastal Basin and joins the Charleston Harbor Estuary from the west near the mouth of the Ashley River and from the east near Sullivans Island. Awendaw Creek, and the Stono River are the principal streams feeding this section of the Intracoastal Waterway which drains into Bulls Bay, Cape Romain Harbor, and numerous sounds and inlets that connect the coastal zone to the Atlantic Ocean.

Charleston Harbor covers an area of approximately 14 square miles. The City of Charleston is located to the west of the harbor, James Island and Morris Island to the south, Mount Pleasant and Sullivans Island to the north, and the Atlantic Ocean to the east. The majority of the upland areas around Charleston Harbor are composed of residential, commercial, and industrial development. The Charleston Harbor Estuary is located in the lower central part of the Coastal Basin and receives flow the from the Intracoastal Waterway, Shem Creek, Dill Creek, James Island Creek, Mill Creek, and Kushiwah Creek within the Coastal Basin. The Ashley, Cooper, and Wando rivers are the principal rivers from the Ashley River and Cooper River basins draining to the Charleston Harbor and are responsible for its formation at their confluence. Charleston Harbor is the discharge point for the Cooper, Ashley, and Wando rivers prior to their ultimate discharge into the Atlantic Ocean.

4.17.2.2 Surface Water Quality

The SCDHEC has identified surface waters in the State of South Carolina in one of the following water quality classifications shown in Table 4.17.2-2. The water quality classifications fall under one of the 4 categories: Freshwaters, Saltwaters, Trout Waters, and Outstanding Resource Waters. Saltwaters and Trout Waters are divided in sub categories related to their use and protection status.

Classifications are based on desired uses, not on natural or existing water quality, and are a legal means to obtain the necessary treatment of discharged wastewater to protect designated uses. Actual water quality may not have a bearing on a waterbody's classification. A waterbody may be reclassified if desired or existing public uses justify the reclassification and the water quality necessary to protect these uses is attainable. A classification change is an amendment to a State regulation and requires public participation, SCDHEC Board approval, and General Assembly approval (SCDHEC (g), 1996).

The water quality standards for the Freshwaters, Saltwaters, Trout Waters and Outstanding Resource Waters are listed in Tables 4.17.2-3 and 4.17.2-4. The water quality standards shown in these tables are used as in stream water quality goals to maintain and improve water quality and also serve as the foundation of a Water Pollution Control Program established by the SCDHEC. The water quality standards are used to determine permit limits for point source treated wastewater dischargers, and non-point sources that may impact water quality. Wasteload allocation models are used to predict the impact a waste water discharger has on a receiving stream. The predicted impacts are used to set limits for different pollutants on the NPDES permits issued by the USEPA. The NPDES permit limits are set so that, as long as a permittee (wastewater discharger) meets the established permit limits, the discharge should not cause a standards violation in the receiving stream. All discharges to the waters in the State of South Carolina require NPDES permits and must abide by those limits, under of penalty of law (SCDHEC (a), 1996).

Natural conditions may prevent a waterbody from meeting water quality goals set forth in the standards shown in Tables 4.17.2-3 and 4.17.2-4. The fact that a waterbody does not meet the standards for a particular classification does not mean the waterbody is polluted or of poor quality. Certain types of water bodies (i.e., swamps, lakes, tidal creeks) naturally have water quality lower than numeric standards. A waterbody can have water quality conditions below standards due to natural causes and still meet its use classification. For instance, runoff filters through swamps and forests, picks up organic materials, and carries them to creeks and rivers. These organic materials consume dissolved oxygen as they decompose in the water. Dissolved oxygen is a critical component in sustaining aquatic life. Several water bodies have been given site-specific standards of pH and dissolved oxygen which reflect natural conditions (SCDHEC (a), 1996).

Table 4.17.2-5 shows the water classifications listed in Table 4.17.2-2 for the majority of the surface waters in the study area as listed in the May 28, 1993 edition of the Classified Waters Regulation 61-69 published by the SCDHEC. The surface waters listed in Table 4.17.2-5 were grouped into one of the eight Cooper River Sub-Basins, one of the two Coastal Sub-Basins and the one Ashley River Sub-Basin in the study area. The locations of these surface waters are shown Figure 4.17.2-1, previously referenced. All surface waters within the study area were classified as Freshwater (FW) or one of the three Saltwater Classifications (SA, SB, and SFH). There are no Trout Water (TN, TGPT and TPT) or Outstanding Resource Water (ORW) Classifications in the study area. However, due to the absence of point source discharges and the presence of endangered species, several streams or portions of streams shown in Table 4.17.2-6 may qualify as potential ORW classifications (SCDHEC (a), 1996).

Where surface waters are not classified with one of the water classifications shown in Table 4.17.2-2, the use classification and water quality standards of the class of stream to which they are a tributary apply, disregarding any site-specific numeric standards for that tributary. Where a surface water body is a tributary to waters of a higher class, the quality of the tributary shall be protected to maintain the standards of the higher classified receiving water (SCDHEC (a), 1996).

Water Quality Monitoring

In an effort to evaluate the state's water quality, the SCDHEC operates a permanent statewide network of primary ambient monitoring stations and flexible, rotating secondary and watershed monitoring stations. The monitoring network is directed towards determining long-term water quality trends, identifying locations in need of additional monitoring efforts, providing background data for planning and evaluating stream classifications and standards, and formulating permit limits for wastewater discharges.

The SCDHEC Water Quality Monitoring Network is comprised of three station types: primary, secondary, and watershed stations. Primary stations are sampled on a monthly basin year-round and are located in high water-use areas or as background stations upstream of high water-use areas. Secondary stations are sampled monthly from May through October and are located in areas where specific monitoring is warranted due to point source discharges, or areas with a history of water quality problems. Watershed stations are sampled on a monthly basis, year-round. Watershed stations are located to provide a more complete and representative coverage within the larger drainage basin for the identification of additional monitoring needs. The monitoring network in the study area includes 24 primary stations, 3 secondary stations, and 2 watershed stations (see Figure 4.17.2-2 for locations). Table 4.17.2-7 shows the station identification number, station type, water body, sub-basin, and description.

The USGS has also maintained a network of continuous water quality monitoring stations since the early 1980's to assist local, state, and Federal agencies in managing the water resources in South Carolina. Currently, the USGS has 12 monitoring stations in the Cooper River Basin, 2 monitoring stations in the Coastal Basin and none in the Ashley River Basin (see Figure 4.17.2-2 for locations). Table 4.17.2-8 shows the USGS station identification number, water body, sub-basin, and description.

Water Quality Parameters

The parameters monitored at the water quality stations include: dissolved oxygen, temperature, pH, salinity, specific conductance, total suspended solids, turbidity, biological oxygen demand, nutrients, heavy metals and fecal coliform bacteria. Detailed descriptions of these parameters are included in Appendix 4.17.

Water Quality Summaries

There have been numerous environmental hydrological, sedimentation, and modeling studies of Charleston Harbor and the Cooper, Wando, and Ashley Rivers (Chestnut, 1989; Kjerfve, 1976; Patterson, 1983; Teeter; 1989; Teeter and Pankow, 1989 ; and Van Dolah 1990, SCDHEC Watershed Water Quality Management Strategy Catawba-Santee Watershed, 1996 and USGS/SCDHEC/Charleston Harbor Project Water Quality Modeling Study 1992-1995). The most recent and comprehensive surface water quality data and interpretations of the existing surface water quality in the Cooper River Basin, Ashley River Basin, and the Coastal Basin are published in the Water Quality Management Strategy Catawba-Santee Watershed, 1996. Therefore, the water quality data and conclusions from this report were summarized to describe the existing water quality in the study area. Water quality data from the USGS/SCDHEC/Charleston Harbor Project Water Quality Modeling Study 1992-1995 was reviewed and compared with the conclusions reported in the assessment of the Catawba-Santee Watershed (see discussion on Charleston Harbor Project). The most recent USGS water quality data from October 1996 to September 1997 was also reviewed.

Recent review of water quality data collected by the SCDHEC and the USGS indicate that the surface waters of the Cooper River, Ashley River and Coastal Basin meet the water classification standards listed in Table 4.17.2-3 for freshwater (FW), and saltwater classifications (SA, SB and SFH). However, the SCDHEC have reported concentrations in surface waters within the study above or below (for DO and pH only) standards of several constituents during their assessment of the Catawba-Santee Watershed (Water Quality Management Strategy Catawba-Santee Watershed, 1996). The SCDHEC assesses the Catawba-Santee Watershed every five years. The next water quality assessment for the Catawba-Santee Watershed is due to be published in October 1999 and will be based on water quality data from 1994 to 1998. The SCDHEC's assessment of the Catawba-Santee Watershed is summarized in Tables 4.17.2-9 and 4.17.2-10. Table 4.17.2-9 shows a summary of the impaired waters in the study area and implementation actions recommended SCDHEC. Waters are considered impaired if they are unable to meet classified uses for aquatic life, recreation or fish consumption based on the corresponding standards. Table 4.17.2-10 shows a summary of the long term trend analysis for the unimpaired waters in the study area. These waters were determined by the SCDHEC to be unimpaired, but exhibit long-term trends that bear following, primarily with continued monitoring. The water quality summaries shown in Tables 4.17.2-9 and 4.17-2-10 were derived from water quality data obtained from the water quality stations listed in Table 4.17.2-6 from 1989 to 1993 (see Appendix 4.17 for water quality results at specific monitoring stations). Water quality and long-term trends in the Cooper River, Wando River, Ashley River, and Charleston Harbor, as reported by the SCDHEC in the Water Quality Management Strategy for the Catawba-Santee Watershed, are given in the following sections.

Cooper River

A fish consumption advisory has been issued by the SCDHEC for the East Branch Cooper River, West Branch Cooper River, and freshwater portions of the Copper River. The advisory includes all tributaries of these three rivers located in the Lake Moultrie, Wadboo Swamp, West Branch Cooper River, East Branch Cooper, River Cooper River, and Back River Sub-Basins. The advisory recommends limits on the amount of some types of fish consumed from the rivers and tributaries in these sub-basins due to mercury contamination.

The reduction in freshwater input to the river due to the Santee River Re-diversion Project (see Santee River Diversion) has resulted in changes in the hydrologic characteristics of the river and may be responsible in part for some of the long-term changes observed in water quality parameters. The Cooper River has been treated annually with aquatic herbicides in an attempt to control the growth of aquatic macrophytes. The plants need to be reduced in high use areas and trails need to be accessed from the rice fields to open water. Cypress Gardens was treated with aquatic herbicides in 1992 to provide boating access and improve aesthetics.

Aquatic life uses are fully supported near the Back River Reservoir Dam, but may be threatened by significantly decreasing trends in dissolved oxygen and pH, and a significantly increasing trend in turbidity. Although the SCDHEC observed excursions in dissolved oxygen and pH, they were typical of values seen in transitional areas between fresh and salt waters and were considered natural, not standard violations. Significantly decreasing trends in total phosphorous and total nitrogen concentrations suggest improving conditions. A high concentration of zinc was measured in 1993. Recreational areas are fully supported, but may be threatened by a significantly increasing trend in fecal coliform bacteria concentration.

Aquatic life uses are fully supported at channel marker 72, but may be threatened by significantly decreasing trends in dissolved oxygen and pH, and a significantly increasing trend in turbidity. Significantly decreasing trends in total phosphorous and total nitrogen concentrations suggest improving conditions. A high concentration of chromium was measured in the 1993 sediment sample. Recreational uses are fully supported, but may be threatened by a significantly increasing trend in fecal coliform bacteria concentration.

Aquatic life uses are also fully supported below the mouth of Goose Creek, but may be threatened by significantly decreasing trends in dissolved oxygen and pH. Decreasing trends in total phosphorous and total nitrogen concentrations suggest improving conditions. Recreational uses are fully supported, but may be threatened by an increasing trend in fecal coliform bacteria concentration.

At the Mark Clark Expressway bridge, aquatic life uses are fully supported, but may be threatened by sediment contamination. In a 1993 sediment sample, the SCDHEC observed very high concentrations of chromium, copper, mercury, nickel, and zinc. In the same sample, the PAHs, acenaphthene, fluoranthene, and pyrene, and PCB-1016 and PCB-1262 were all detected at concentrations above detection limits. Recreational uses are not supported due to fecal coliform bacteria excursions.

At channel marker 49, upstream of Shipyard Creek, aquatic life uses are fully supported, but may be threatened by significantly decreasing trends in dissolved oxygen and pH. Significantly decreasing trends in total phosphorous and total nitrogen concentrations suggest improving conditions. In a 1991 sediment sample, high concentrations of chromium and zinc were measured. Recreational uses are only partially supported due to fecal coliform bacteria excursions.

Aquatic life uses are fully supported under the Grace Memorial Bridge, but may be threatened by a significantly decreasing trend in dissolved oxygen and a significantly increasing trend in turbidity. Significantly decreasing trends in total phosphorous and total nitrogen concentrations suggest improving conditions. Recreational uses are fully supported.

On the Town Creek side of Drum Island under the Grace Memorial Bridge, aquatic life uses are fully supported, but may be threatened by a significantly decreasing trend in dissolved oxygen and a significantly increasing trend in turbidity. Significantly decreasing trends in total phosphorous and total nitrogen suggest improving conditions. Recreational uses are only partially supported due to fecal coliform bacteria excursions.

Wando River

The SCDHEC has observed dissolved oxygen excursions at two water quality monitoring sites in the Wando River during the 1989-1993 assessment of the Catawba-Santee watershed. The dissolved oxygen excursions were typical of values seen in tidally influenced systems with significant marsh drainage and were considered to be natural in origin, not standards violations. Aquatic life may not be supported at the upstream site (MD-115) due to very high concentrations of copper, cadmium and zinc observed by the SCDHEC in 1989, compounded by significantly declining trends in dissolved oxygen concentration and pH. In a 1991 sediment sample at station MD-115, the SCDHEC observed high concentrations of copper and zinc. In a 1993 sediment sample at station MD-115, the SCDHEC observed high concentrations of chromium, copper, and zinc. Significantly decreasing trends in five-day biochemical oxygen demand, total phosphorous, and total nitrogen concentrations suggest improving conditions. Recreational uses are fully supported.

At the downstream water quality monitoring site (MD-198), aquatic life uses are fully supported, but may be threatened by a significantly declining trend in dissolved oxygen concentration. Significantly decreasing trends in total phosphorous and total nitrogen concentrations suggest improving conditions. Recreational uses are fully supported, but may be threatened by a significantly increasing trend in fecal coliform bacteria concentrations.

Ashley River

The SCDHEC observed low dissolved oxygen values and acidic pH values at the four water quality monitoring sites in the Ashley River during the 1989-1993 assessment of the Catawba-Santee watershed. Although low dissolved oxygen values and acidic pHs are typical of tidally influenced systems with significant marsh drainage, the occurrence of decreasing trends and an increasing frequency of low values seen at several sites suggests potential developing problems.

Aquatic life uses are not supported at the furthest upstream site (MD-049) due to dissolved oxygen excursions, compounded by significantly decreasing trends in dissolved oxygen and pH. Recreational uses are not supported due to fecal coliform bacteria excursions, compounded by a significantly increasing trend in fecal coliform bacteria concentrations.

Aquatic life uses are not supported at station MD-242 due to dissolved oxygen excursions. Recreational uses are not supported due to fecal coliform bacteria excursions. Aquatic life uses are also not supported at station MD-135 due to dissolved oxygen excursions, compounded by a significantly decreasing trend in dissolved oxygen concentration and a significantly increasing trend in turbidity. Recreational uses are only partially supported due to fecal coliform bacteria excursions.

Aquatic life uses are also not supported at station MD-052 due to dissolved oxygen excursions, compounded by a significantly decreasing trend in dissolved oxygen concentration and a significantly increasing trend in turbidity. Significantly decreasing trends in total phosphorous and total nitrogen concentrations suggest improving conditions. In a 1990 sediment sample, the SCDHEC observed a high concentration of nickel and the pesticide phosdrin was detected at a concentration well above the detection limit. Recreational uses are only partially supported due to fecal coliform bacteria excursions.

Aquatic life uses are fully supported at the river mouth to Charleston Harbor, but may be threatened by a significantly decreasing trend in dissolved oxygen concentration and a significantly increasing trend in turbidity. Significantly decreasing trends in total phosphorous and total nitrogen concentrations suggest improving conditions. Recreational uses are only partially supported due to fecal coliform bacteria excursions.

Charleston Harbor

The SCDHEC reported in their assessment of the Catawba-Santee Watershed that aquatic life uses are fully supported at the river mouth to Charleston Harbor, but may be threatened by significantly decreasing trend in dissolved oxygen concentration and a significantly increasing trend in turbidity. Significantly decreasing trends in total phosphorous and total nitrogen concentrations suggest improving conditions. Recreational uses are only partially supported due to fecal coliform bacteria excursions.

The SCDHEC also reported in their assessment of the Catawba-Santee Watershed that recreational uses are fully supported for the remaining portions of Charleston Harbor. In the vicinity of the Mount Pleasant wastewater treatment plant diffuser discharge, aquatic life uses are fully supported. However, a significantly increasing trend in pH was detected.

At the Fort Johnson pier, aquatic life uses area are fully supported, but may be threatened by a significantly increasing trend in turbidity. Significantly decreasing trends in total phosphorous and total nitrogen concentrations suggest improving conditions.

Aquatic life uses are fully supported in the south channel at bell buoy 28, but may be threatened by a significantly decreasing trend in dissolved oxygen concentrations and significantly increasing trends in pH and turbidity. A high concentration of zinc was measured in 1992 and a high concentration of nickel was measured in 1990. Significantly decreasing trends in five day biochemical oxygen demand, total phosphorous, total nitrogen, and fecal coliform bacteria concentrations suggest improving conditions.

Charleston Ocean Dredged Material Disposal Site

The EPA monitors water quality at the Charleston Ocean Dredged Material Disposal Site. The most recent water quality data at this site are summarized in Table 4.17.2-11.

Charleston Harbor Project

In May 1992, the USGS, in cooperation with the SCDHEC, Office of Ocean and Coastal Resource Management (OCRM) and Charleston Harbor Project, initiated a study to develop digital simulation models of water quality in the Ashley, Cooper, and Wando Rivers, and in the Charleston Harbor. The purpose of the study was to apply a one-dimensional unsteady flow model (BRANCH) and the Branch Lagrangian Transport Model (BLTM) to the Cooper River and its major tributaries from the Pinopolis Dam to its confluence with the Wando River, the Wando River from its headwaters to the confluence with the Cooper River, and the Ashley River from Bacon Bridge downstream to the Highway 17 bridge. One of the goals of the Charleston Harbor Project was to develop a tool for SCDHEC use in point source wasteload allocation and total maximum daily load determination.

To support the model development, water quality data from the permanent USGS stations (see Table 4.17.2-8) and additional temporary USGS stations and permanent SCDHEC water quality stations were added to the data collection network in 1992. From October 1991 to September 1995, hydrologic and water-quality data were collected from these stations. Both continuous and discrete data were collected. Continuous water quality data include specific conductance, pH, temperature, and dissolved oxygen data. Discrete water quality data include nutrient, biochemical oxygen demand, and suspended-sediment concentrations. Summaries of the data are included in Appendix 4.17.

Activities Potentially Affecting Water Quality

The quality of surface water can be affected by pollution originating from point and non-point sources. Point and non-point sources in the study area are described in the following sections.

Point Source Contributions

The SCDHEC defines a point source as any discernible, confined, and discrete conveyance, including but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, landfill leachate collection system, vessel or other floating craft from which pollutants are or may be discharges. This term does not include return flows from irrigated agriculture or agricultural stormwater runoff. (SCDHEC (a), 1996)

Currently, there are 53 industries and 28 municipalities under the NPDES that are permitted to discharge into the surface waters in the study area (see Appendix 4.17 and Figure 4.17.2-3) (Watershed Water Quality Management Strategy, 1996). Thirty-six industrial and 15 municipal NPDES permitees discharge into the Cooper River. Ten of the dischargers in the Cooper River (five industrial and five municipal) are major facilities that have discharge flows in excess of 1.0 Mgal/d. Twenty-six of the dischargers in the Cooper River, including nine of the major facilities, are located below the confluence of the West Cooper River and East Cooper River. Ten industrial and 6 municipal NPDES permitees discharge into the Ashley River. Four of the dischargers into the Ashley River (four municipal minor) are major facilities that have discharge flows in excess of 1.0 Mgal/d. One minor industrial NPDES permittee discharges into the Wando River, with a discharge of less than 1.0 Mgal/d. Six industrial and 7 municipal NPDES permitees discharge into the Intracoastal Waterway, Charleston Harbor, and their tributaries. One major industrial NPDES permittee discharges into Charleston Harbor, with a discharge in excess of 1.0 Mgal/d.

The Domestic Wastewater Division and the Industrial and Agricultural Wastewater Division of the SCDHEC are responsible for drafting and issuing NPDES permits to the dischargers listed in Table 8 in Appendix 4.17. All NPDES permits were issued, or reissued on September 30, 1995, and will be reissued in 2000. The NPDES permit places an effluent or water quality limitation. Streams are designated either effluent limited or water quality limited based on the level of treatment required of the dischargers to that particular portion of the stream. In cases where the USEPA published effluent guidelines, the minimum treatment levels required by law are sufficient to maintain in stream water quality standards, and the stream is said to be effluent limited. Streams lacking the assimilative capacity for a discharge at minimum treatment levels are said to be water quality limited. In cases where better than technology limits are required, actual water quality, not minimum requirements control the permit limits. (SCDHEC (a), 1996)

A wasteload allocation is the portion of a stream's assimilative capacity for a particular pollutant which is allocated to an existing or proposed point source discharge. Existing wasteload allocations are updated by the SCDHEC and included in permits during the normal permit expiration and reissuance process. New wasteload allocations are developed for proposed projects seeking a discharge permit or for existing discharges proposing to increase their effluent loading at the time of application. The SCDHEC Wasteload Allocation Department recommends limits for numerous parameters including ammonia nitrogen (NH_3-N), dissolved oxygen (DO, total residual chlorine (TRC), and five day biochemical oxygen demand (BOD_5). Limits for other parameters, including metals, toxics, and nutrients are developed by the Municipal Wastewater Division or Industrial and Agricultural Wastewater Divisions of the SCDHEC. (SCDHEC (a), 1996)

Section 303d of the Clean Water Act requires states to identify waters that are water quality impaired, as a result of non-attainment of point and nonpoint source water quality related standards, or if controls more stringent than minimums set in effluent guidelines are deemed necessary. Impaired surface waters are classified as low priority or high priority. Water bodies included on the 303(d) high priority list are targeted for Total Maximum Daily Load (TMDL) development. Water bodies on the low priority may require TMDL development. A TMDL is the calculated maximum allowable pollutant loading to a waterbody at which water quality standards are maintained. Section 304(l) of the Clean Water Act requires states to identify all point sources discharging any toxic pollutant that is believed to be impairing stream water quality and to indicate the amount of the toxic pollutant discharged by each source (SCDHEC (a), 1996). Table 4.17.2-12 shows the surface waters within the Copper River, Ashley River, and Coastal Basins included in the 303(d) low and high priority lists and 304(l) list.

Non-Point Source Contributions

Non-point source pollutants are generally introduced to a waterbody during a storm event and enter surface waters from diverse areas. Stormwater runoff arises from precipitation during rain events, which washes runoff from industrial, agricultural, construction, urban areas and household sites directly into streams or into drainage systems that eventually drain into streams.

The EPA National Stormwater Permit Program focuses on municipal and industrial pollution prevention to assist in controlling stormwater pollution. The SCDHEC has general permit authority for industrial dischargers and regulated construction site dischargers. General permits require development of pollution prevention plans to identify Best Management Practices (BMPs) that will control stormwater discharge pollutants. If the BMPs are ineffective in protecting water quality, an individual permit is required to resolve the problem.

The SCDHEC is responsible for issuing NPDES stormwater permits to prevent degradation of water quality. The SCDHEC also issues permits for sediment and erosion control for construction sites. NPDES permits for municipal systems allow communities to design stormwater management programs that are suited for controlling pollutants in their jurisdiction. There are two population based categories of municipal separate storm sewers: large municipal (population greater than 250,000) and medium municipal (population between 100,000 and 250,000). (SEDHEC (a), 1996) In the study area, Charleston County and the City of Charleston are considered large municipal and must obtain a comprehensive municipal permit within their jurisdiction. All other municipalities in the study area are defined as medium municipalities.

Section 319 of the 1987 Amendments to the Clean Water Act require states to assess the nonpoint source water pollution and implement a management strategy to control and abate the pollution. In response to Amendment 319, the SCDHEC created a Non-Point Source (NPS) Management Program which develops strategies and targeted water bodies for priority implementation of management projects. Components of the projects include Best Management Practice (BMP) demonstrations, education, and monitoring. Best management practices are schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce surface water pollution. BMPs include treatment facilities, operating procedures, and practices to control plant site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage. Table 4.17.2-12 shows the surface waters impacted by urban runoff within the Copper River, Ashley River, and Coastal Basins included on the 319 list.

4.17.2.3 Surface Water Quantity

This section describes surface water flow, tide stages, and a brief discussion on the re-diversion of the Santee River.

Surface Water Flow

Stream flow data for the Cooper, Wando, and Ashley rivers were obtained from field measured data used in the calibrations and validation of the one-dimensional unsteady flow model (BRANCH) applied in the water quality study of the Charleston Harbor, Cooper River, Wando River, and Ashley River for the Charleston Harbor Project. Flows were measured from bridges and boats at one permanent USGS monitoring station on the Copper River, five temporary monitoring stations on the Wando River, and four temporary monitoring stations on the Ashley River. Although the USGS attempted to measure flow over a complete flood- and ebb-tidal cycle, most measurements covered a 10-hour period. Maximum positive or negative flows were measured in most cases. Positive flows move in the direction of the ebb tide (seaward direction) and negative flows move in the direction of the flood tide (upstream direction). Measurements on the Cooper River were made on July 29, 1992, September 2, 1992, and February 16, 1995. Measurements on the Wando River were made on July 30 and September 24, 1992. Measurements on the Ashley River were made on July 28 and September 25, 1992. Locations of the ten streamflow-monitoring stations are shown on Figure 4.17.2-4 and listed with the respective flow data on Table 4.17.2-13.

Stream flow data for the Cooper River is also continuously monitored at the same USGS monitoring station (02172002) used in the Charleston Harbor Project Water Quality Study. This station is located approximately 2.2 miles below the Pinopolis Dam at Lake Moultrie and is the only active streamflow gaging station in the study area. The USGS publishes stream flow data annually in the USGS Survey Water Data Report for a water year. The USGS also published a summary of the water quality and hydrologic data for calendar years 1991, 1992, 1993, and 1994 and water year 1995 for the Charleston Harbor Project Water Quality Study. Table 4.17.2-14 shows streamflow data at Station 02172002 for calendar years 1991, 1992, 1993, 1996 and water year 1997.

Re-diversion of the Santee River

The Santee-Cooper Project was implemented in the 1930's because of the increased demand for electric power. The Santee-Cooper Project was completed in 1941 and created two freshwater lakes by diverting flows from the Santee River with the construction of the Wilson Dam across the Santee River to form Lake Marion and the construction of the Pinopolis Dam near the headwaters of the West Branch Cooper River to form Lake Moultrie. A four-mile diversion canal was built to connect the two lakes. The water-surface elevation difference between the Lake Moultrie and the West Branch Cooper River is approximately 70 feet. The diverted flows from the Santee River through the Pinopolis Dam to the West Branch Cooper River had pronounced effects on the Cooper River and the Charleston Harbor. The Cooper River was transformed from a tidal slough with a mean annual downstream flow of 71 ft^3/s to a riverine system with a mean annual flow of 15,600 ft^3/s. The diversion of water transformed Charleston Harbor from a well-mixed estuary to a partially mixed estuary and an effective sediment trap. After diversion, shoaling in navigation channels of Charleston Harbor jumped from about 110,000 cubic yards to over 10 million cubic yards per year and through improved dredging and disposal methods, stabilized at about 7.5 million cubic yards per year. Additionally, mean salinity values in Charleston decreased from 31 to 16 ppt (parts per thousand).

In 1985, the U.S. Army Corps of Engineers (USACE) re-diverted flows from Lake Moultrie back to the Santee River to alleviate a severe sedimentation problem in Charleston Harbor created by the diversion of freshwater flows. The re-diversion was accomplished by building an 11-mile re-diversion canal from Lake

Moultrie to the Santee River. After the re-diversion project, the flows to the Cooper River were reduced from the annual mean flow of 15,600 ft^3/s to a weekly mean flows between 3,000 and 4,500 ft^3/s, a level that would alleviate sedimentation in the harbor while ensuring an adequate freshwater source to the Brushy Park Reservoir at the mouth of the Durham Canal.

Tidal Information

The Charleston Harbor, Cooper River, Wando River, Ashley River, and their tributaries experience semi-diurnal tides. The National Oceanic and Atmospheric Administration (NOAA) monitors 4 tidal benchmark stations in Charleston Harbor, 16 in the Cooper River and tributaries, 5 in the Wando River and tributaries, and 7 in the Ashley River and tributaries (see Figure 4.17.2-5). Table 4.17.2-15 shows the latitude, longitude, tide elevations referred to mean lower low water, and mean and spring ranges. The reference station is the Custom House Station (Bench Mark Station 866-5530). The reference station has independent daily tide predictions published by NOAA. The remaining stations shown in Table 4.17.2-15 are subordinate stations, where corresponding daily tide predictions are obtained by means of difference and ratios respective to the reference station (Tide Tables for the East Coast of North and South America 1998 Edition). The Custom House Station is the only station with a National Geodetic Vertical Datum-1929 (NGVD) at 2.43 feet and a Charleston Low Water Datum (CLW) at -0.21 feet. Conversions from Mean Lower Low Water (MLLW) to NGVD or CLW at the Custom House Stations are conducted by taking the difference from the elevations referred to MLLW with the respective datum. Conversions from MLLW to NGVD or CLW at the subordinate station are conducted by taking the difference from the elevations referred to MLLW with respective datum after adjusting elevations with the aforementioned differences and ratios published by NOAA.

The extreme tidal ranges and saltwater prism for Charleston Harbor, Cooper River, Wando River, and Ashley River are described in the following paragraphs.

The Charleston Harbor experiences mean and spring tidal ranges of 5.13 and 5.95 feet, respectively, at the harbor entrance from the Atlantic Ocean at The Cove near Fort Moultrie and has mean- and spring tidal ranges of 5.27 and 6.11 feet, respectively, at the Customs House near the peninsula of the City of Charleston. The Cooper River is tidally affected throughout its entire reach up to the Tailrace Canal, and has mean- and spring tidal ranges of 5.40 and 6.26 feet, respectively, at the south entrance of Clouter Creek on the lower Cooper River near Daniel Island and mean- and spring tidal ranges of 1.70 and 1.97 feet, respectively, at Pimlico on the West Branch Cooper River. Saltwater in the Cooper River extends from the harbor upstream to several miles below the confluence of the West Branch Cooper River and East Branch Cooper River.

The tidal ranges in the Wando River amplify as they progress upstream. Mean- and spring tidal ranges at Hobcaw Point , near the confluence with the Cooper River, are 5.44 and 6.31 feet, respectively. As the tide progresses upstream, the mean- and spring tidal ranges increase to 6.54 and 7.59 feet, respectively, at Big Paradise Island. Saltwater extends throughout the entire Wando River.

The Ashley River is tidally affected throughout its entire reach up to Bacon Bridge and has mean- and spring tidal ranges of 5.36 and 6.22 feet, respectively, at James Island Creek on the lower Ashley River near

Charleston Harbor and mean- and spring tidal ranges of 1.94 and 2.25 feet, respectively, at Bacon Bridge. Saltwater extends throughout the Ashley River from the entrance to Charleston Harbor to Bacon Bridge.

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